

Advanced Photodetection Concepts

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MONITOR

HOMELAND DEFENSE & SECURITY

Homeland Security ♦ Defense ♦ Energy ♦ State

Anti-Terrorism, Counterterrorism, First Response, Force Protection & Physical Security Technologies

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— INSIDE HIGHLIGHTS —

The Senate unanimously passed the FY07 Homeland Security Appropriations bill July 13 amid a torrent of criticism from lawmakers of the management of the Dept. of Homeland Security, its prioritization of problems and the lack of overall preparedness. 2

The Dept. of Homeland Security awarded three contracts July 14 for development of its Advanced Spectroscopic Portal to supplement current radiation portal monitors by reducing false alarm rates. 4

Legislation introduced by House Homeland Security Committee Ranking Member Bennie Thompson (D-Miss.) June 29 to strengthen transportation security days could be brought to the top of Congress's agenda after the devastating attacks in India earlier this month. 6

A House Homeland Security subcommittee passed legislation July 11 to strengthen chemical facility security across the country that is generally in-line with that proposed in the Senate Homeland Security and Government Affairs Committee bill reported out last month. 6

Researchers at the University of California, Davis working on a prototype gamma ray detector are incorporating flat screen technology used in televisions that they believe could reduce the cost of such detectors 100-fold and enable their use in a variety of homeland security applications. 7

The Dept. of Homeland Security released guidance July 6 for nearly \$400 million in grants available in FY06 to protect critical infrastructure sites across the country, including transit systems, seaports and chemical facilities. 8

The Dept. of Homeland Security unveiled its National Infrastructure Protection Plan June 30, outlining the roles of various government agencies, the private sector, and academia in securing key facilities within the United States. . . . 9

The government's Interagency Security Committee should develop and distribute guidance for ensuring facility security, as current assessments do not accurately reflect the performance of security efforts, according to a Government Accountability Office letter report released July 7. 9

The Department of Homeland Security's National Asset Database is too large and includes several questionable facilities, the Department's Inspector General contends in a recent report, saying the faults "could lead to inefficient use of limited homeland security resources." 10

Despite recent technology advances in nuclear detectors, the core of the nuclear detection capabilities along U.S. borders remains in the hands of 100 volunteers at three Dept. of Energy national laboratories. 11

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REP. BENNIE THOMPSON (D-MISS.) ON CHEMICAL PLANT SECURITY Pg. 12

Very rare and/or weak radiation phenomena

- **Nuclear Proliferation and homeland security**
- **Proton Decay**
- **Neutrino Physics**
- **Geo-neutrino Physics**
- **Neutrino Astrophysics**
- **Gamma-ray Astronomy**
(low detection threshold + wide acceptance angle)
- **Ultra-high energy cosmic rays ($>10^{19}$ eV)**
- **Neutrinoless Double Beta Decay (SuperNemo)**
- **Dark Matter Search**

DETECTION OF NUCLEAR MATERIALS

VIA RADIATION

INTRINSIC (n, γ, ν)

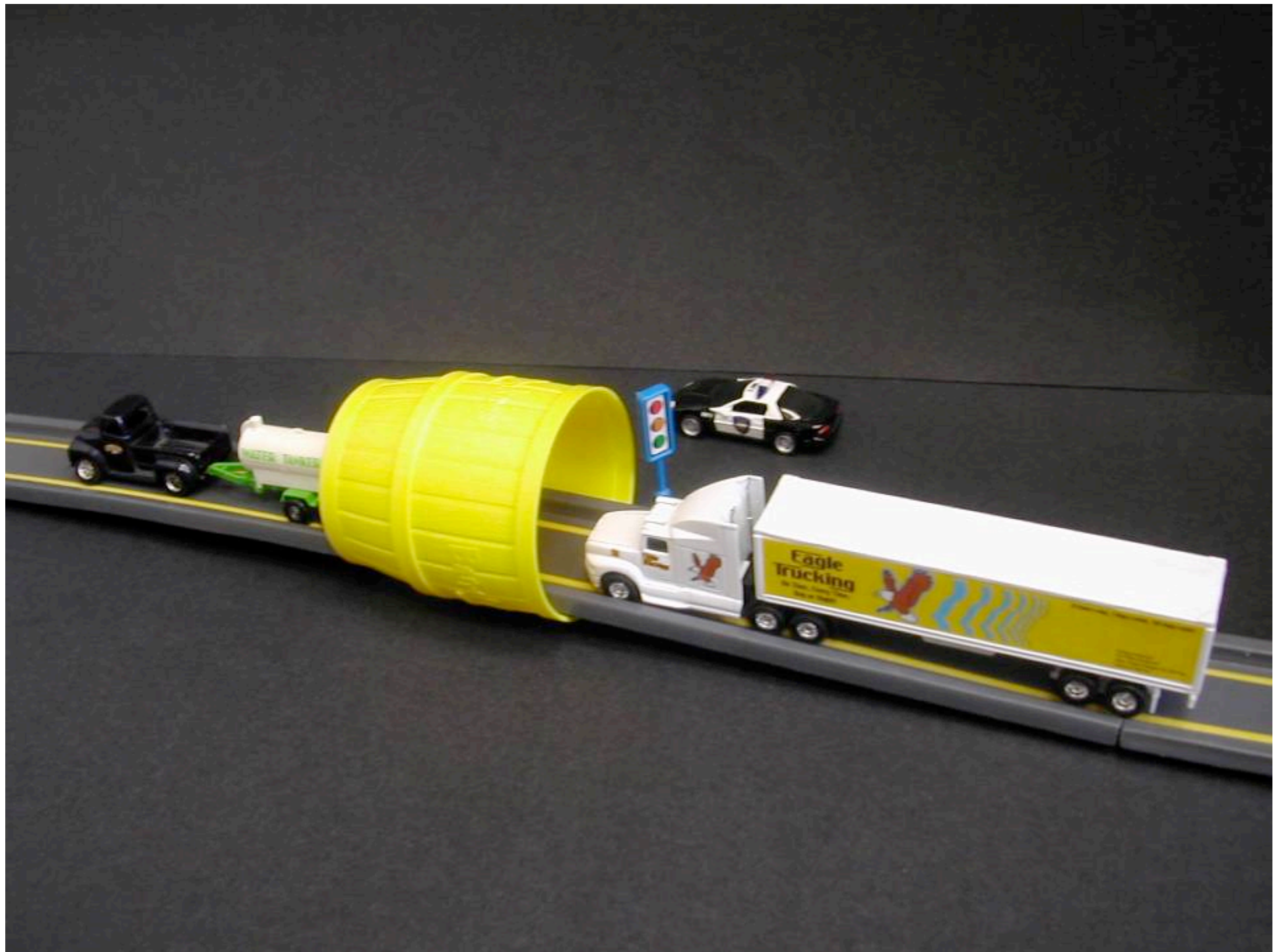
- HE Uranium
- Any-grade Plutonium
Weak radiation

INDUCED (γ)

NEUTRON ACTIVATION
Limited to low (harmless)
doses

DETECTION SYSTEMS
→ VERY LARGE
(EMBEDDING)

**Every bit of
radiation is
PRECIOUS**



**REQUIREMENTS ON
NUCLEAR DETECTION SYSTEMS**
(containers, vehicles etc.)

```
graph TD; A["REQUIREMENTS ON<br/>NUCLEAR DETECTION SYSTEMS<br/>(containers, vehicles etc.)"] --> B["→ VERY LARGE AREA<br/>(EMBEDDING the OBJECT)"]; A --> C["→ MANY DETECTORS<br/>(COMPREHENSIVE)"]; B --> D["→ INDUSTRIALLY MASS-PRODUCED<br/>→ INEXPENSIVE<br/>→ ROBUST and RELIABLE<br/>→ EASILY DEPLOYABLE"]; C --> D;
```

→ VERY LARGE AREA
(EMBEDDING the OBJECT)

→ MANY DETECTORS
(COMPREHENSIVE)

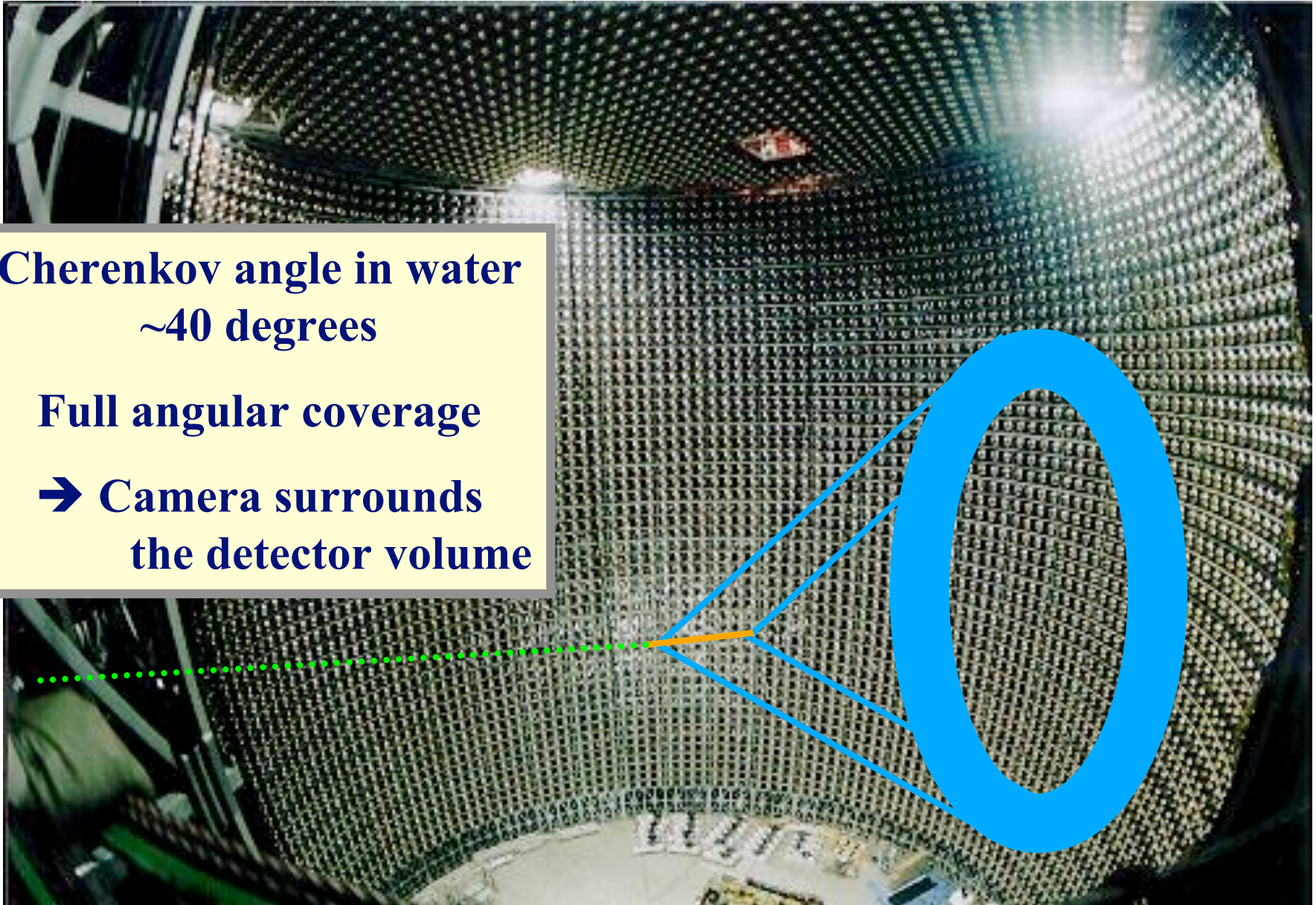
- INDUSTRIALLY MASS-PRODUCED**
- INEXPENSIVE**
- ROBUST and RELIABLE**
- EASILY DEPLOYABLE**

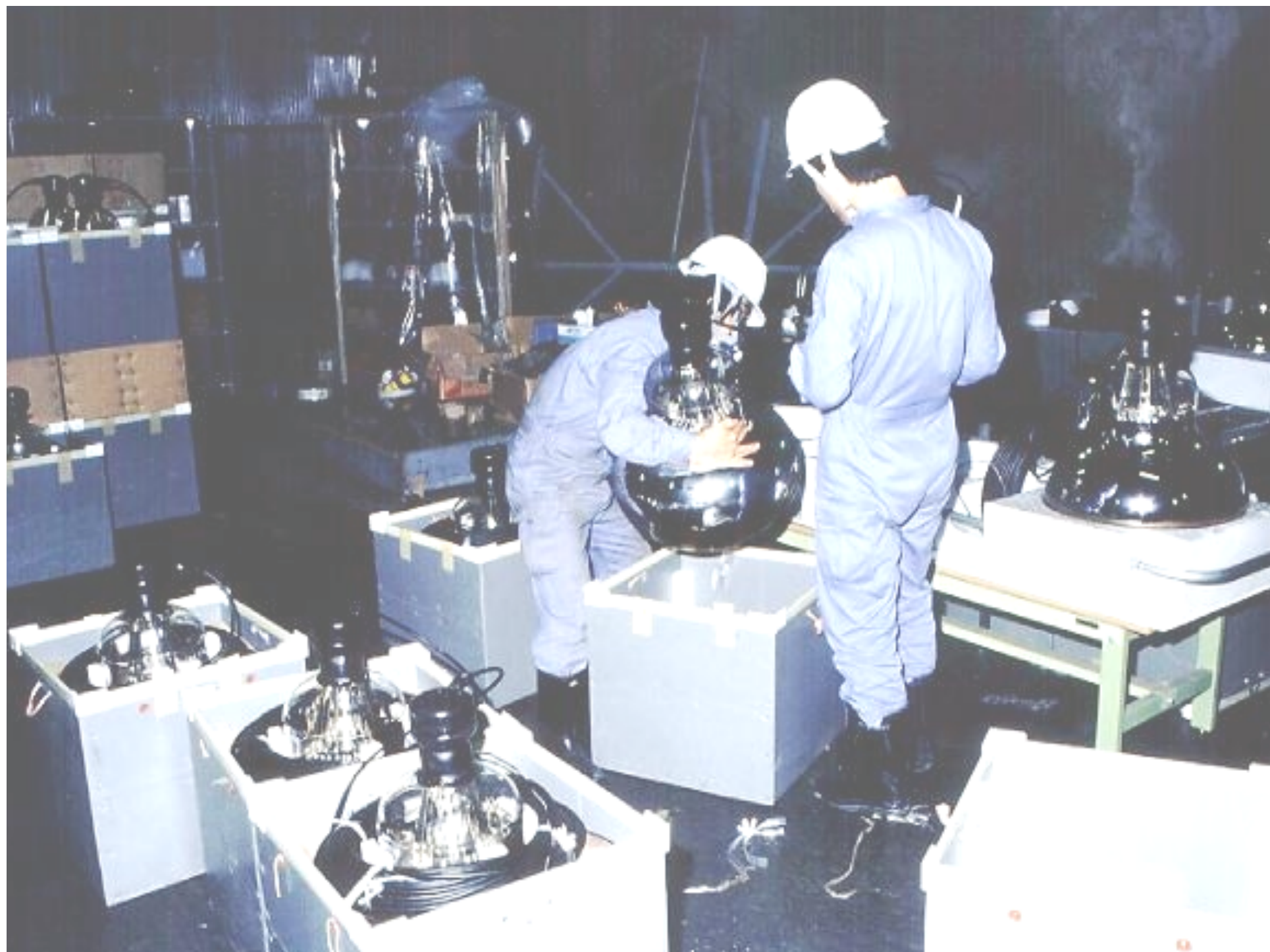
The Unbeatable Reality of Mr. Liouville

**Cherenkov angle in water
~40 degrees**

Full angular coverage

**→ Camera surrounds
the detector volume**





UNO Detector Conceptual Design

A Water Cherenkov Detector
optimized for:

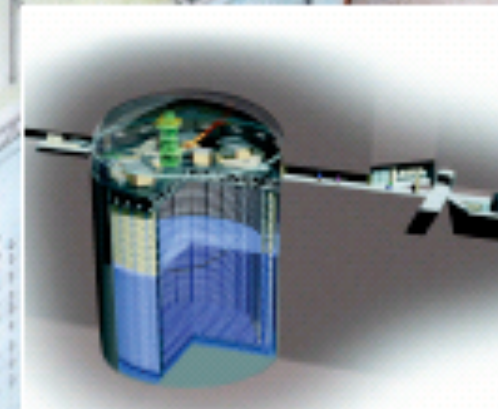
- Light attenuation length limit
- PMT pressure limit
- Cost (built-in staging)

UNO Coll

99 D

ions

ountries



1 MEGATON WATER CHERENKOV DETECTOR

10%

40%

Only optical
separation

60x60x60m³x3

Total Vol: 650 kton

Fid. Vol: 440 kton (20xSuperK)

of 20" PMTs: 56,000

of 8" PMTs: 14,900

WHY

(1) THE PMT COST IS HIGH

(2) THE QUANTITY IS LIMITED

?

50% - DYNODE COLUMN

50% - GLASS BULB

→ HAND-MADE COMPONENTS

**→ CLOSED CONFIGURATION
(a PMT is partly 'made in itself')**

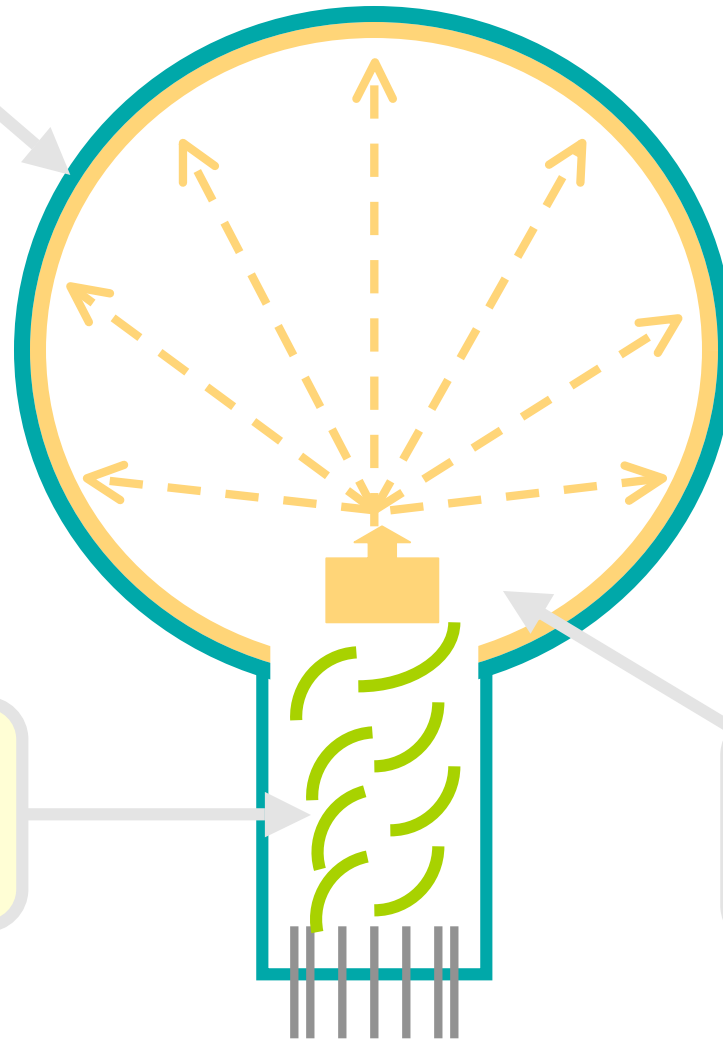


Every PMT – ‘its own factory’

handmade

handmade

Cs, K, Na, Sb



A GLASS TUBE FACTORY

$\sim 100\times$



SciFi PMT DYNODE FACTORY



Development of Other Vacuum Devices



~1960



~2000

Production Cost '06 < \$1,000/m²

OUR GOAL

to introduce a new Technology for

industrial mass production

of large quantities

of large photosensors

based on modified existing technologies

+ FOCUS on some 'REAL' (non-physics) MARKETS

**ENCLOSURE:
FLAT-PANEL TV**



**3 existing
mass-production
technologies**

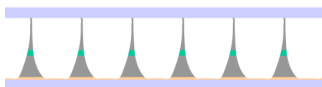
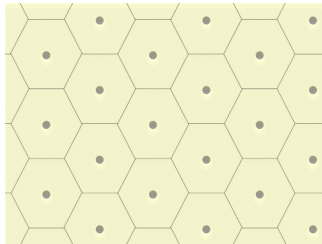
**PHOTON→ELECTRON
CONVERSION:
CLASSICAL
PHOTOCATHODE**

**ELECTRON DETECTION:
SEMICONDUCTOR
Scintillator + Geiger-MODE
AVALANCHE
DIODE
'Light Amplifier'**

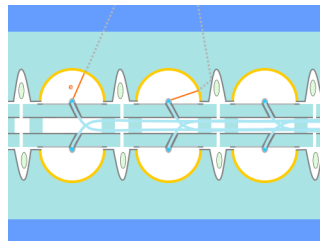
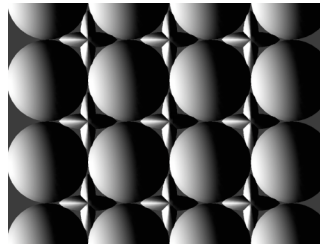
Advanced Photosensors

**ULTIMATE:
FLAT-PANEL**

ReFERENCE

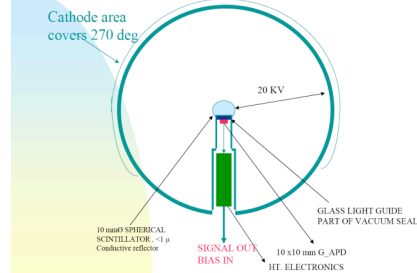


ArcaLux



**INTERMEDIATE:
HEMISPHERICAL
Light Amplifier**

A SPHERICAL SOLUTION WITH SPHERICAL SCINTILLATOR, SIMPLE PRODUCTION
5 STERAD, MINIMAL TIME JITTER, ELECTRONICS CAN BE LOCATED IN STEM
MAY BE EVEN PRODUCED INSIDE BENTOS SPHERE



**ENCLOSURE:
FLAT-PANEL TV**



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CANDESCENT

Field-emission display company, San Jose, CA

\$ 600 Millions

5-inch
prototypes

TECHNOLOGY

R&D EQUIPMENT

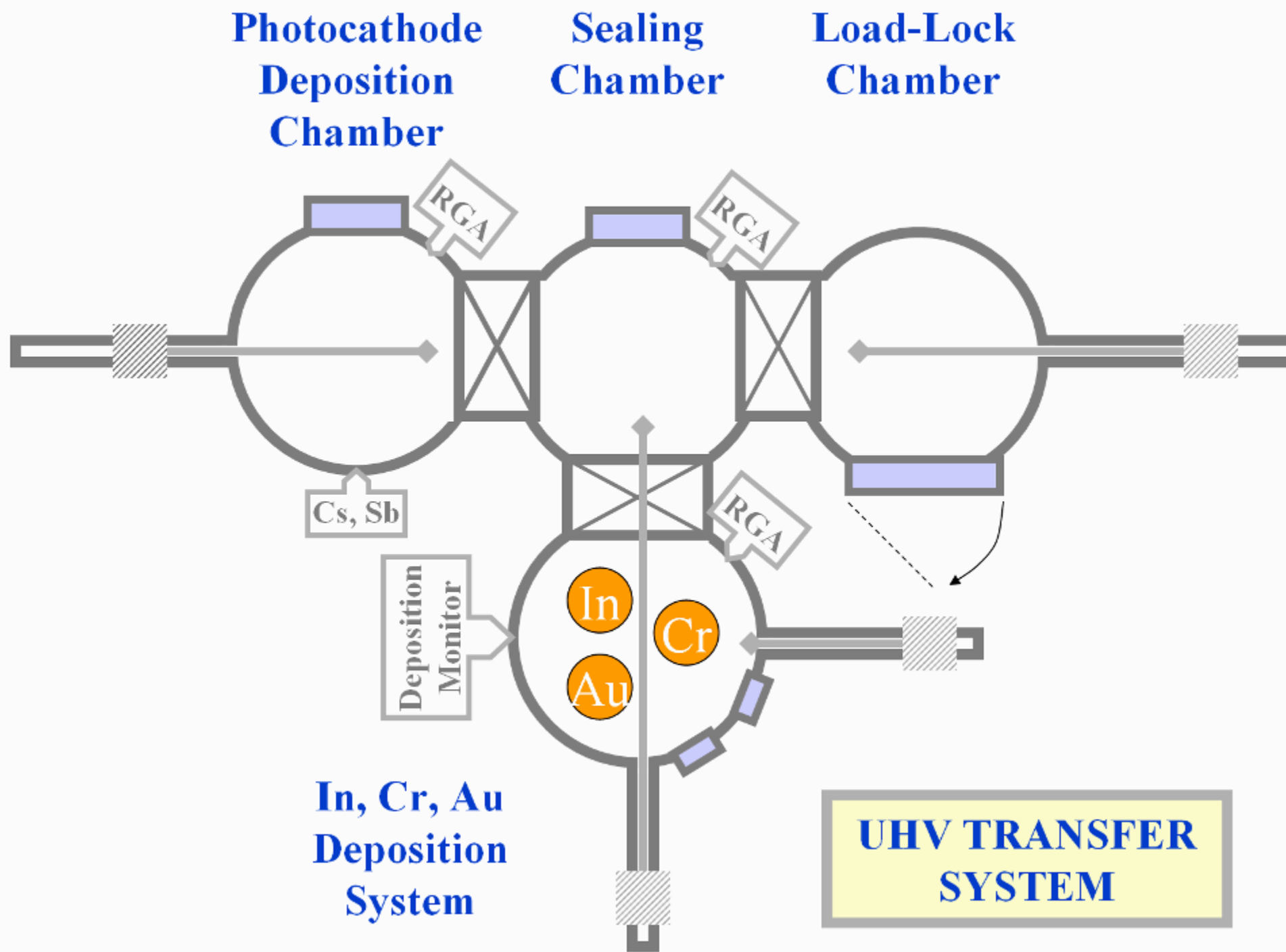
CANON-TOSHIBA
SED Display (2006)

$\sim 1 \text{ m}^2$

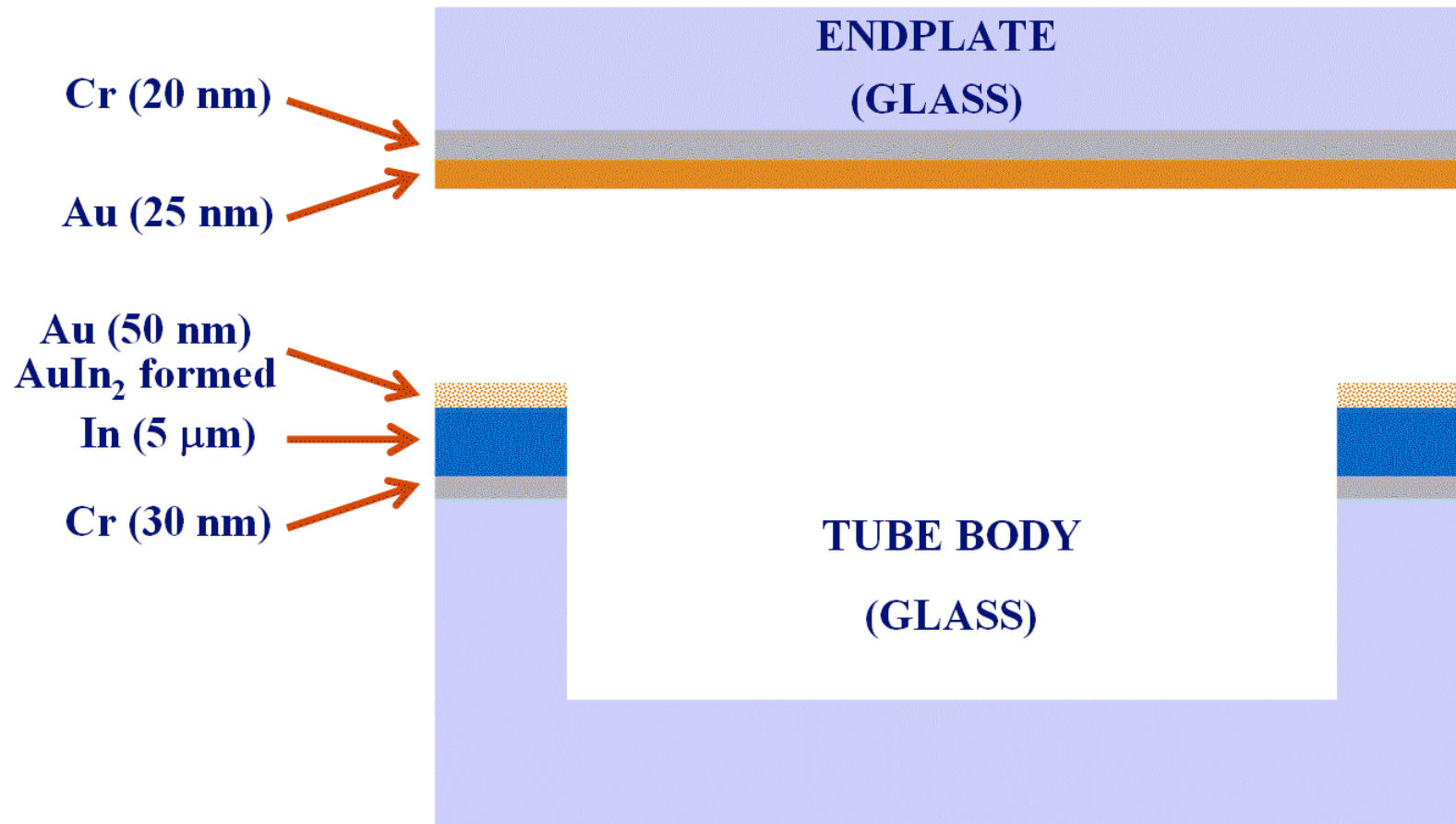
Our LAB @
UC Davis

\$ 2 B

\$ 1 M

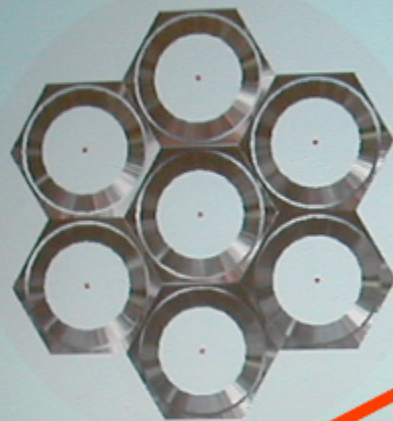


New Oxide-Free Indium Sealing Method



See NIM-A paper, D. Ferenc, E. Lorenz et al. 2006 (in press)

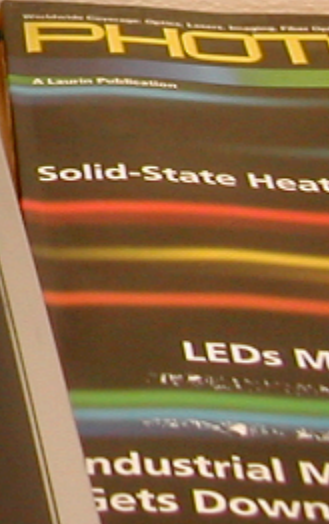
ReFeRence Panel Prototype (under construction)

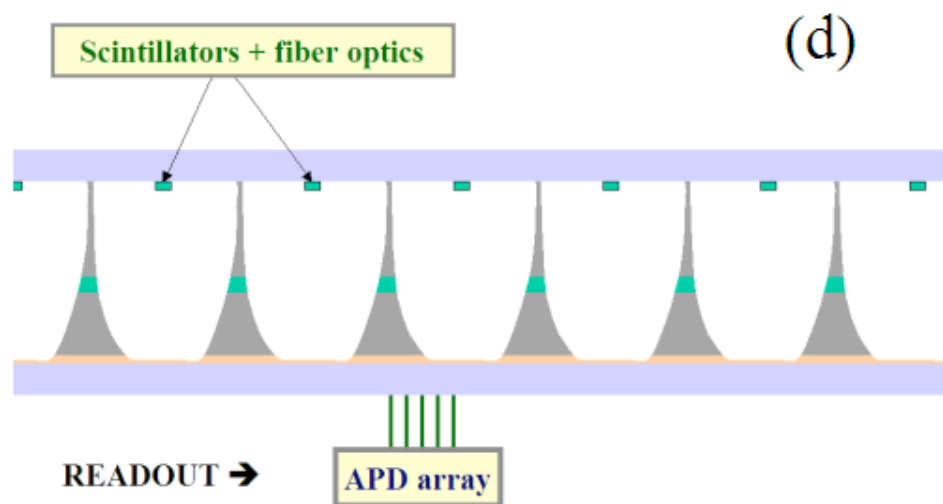
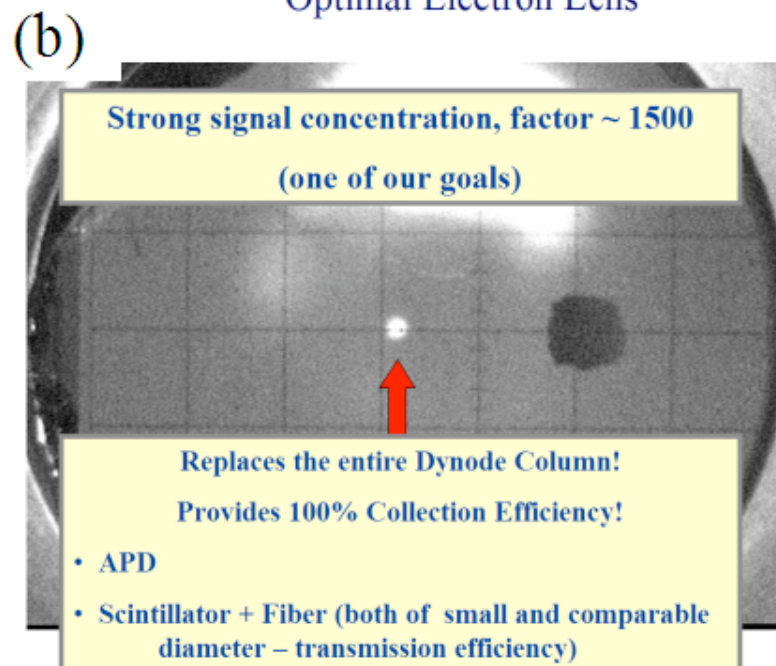
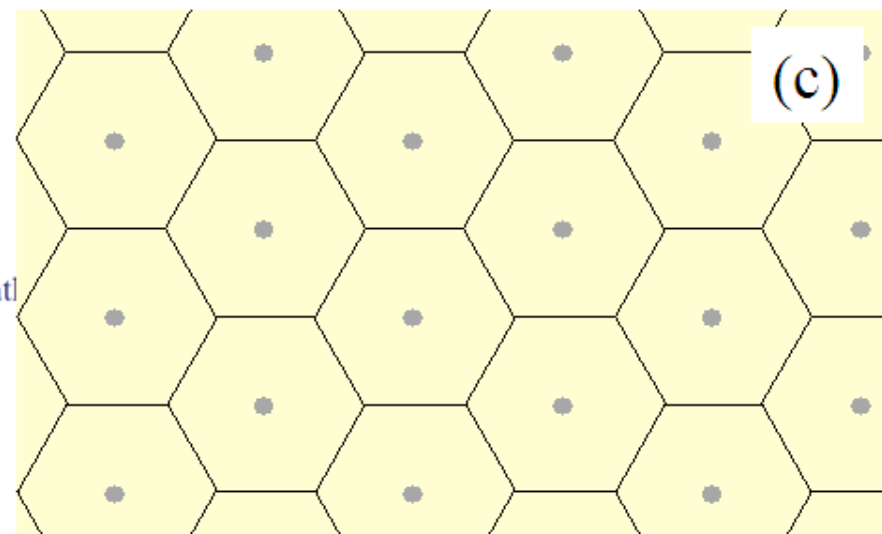
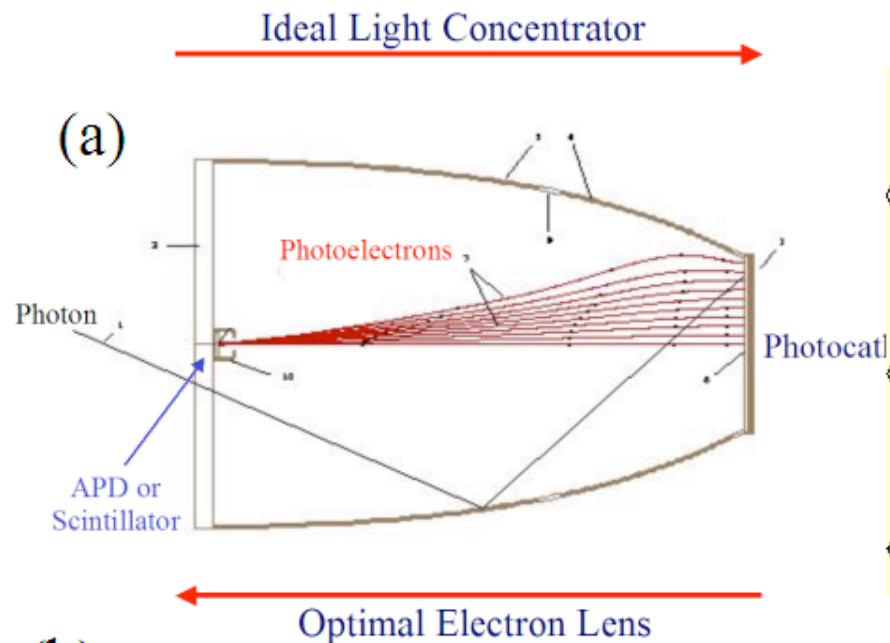


ENDPLATE

**TUBE
BODY**

TOSHIBA





‘ArcaLux’

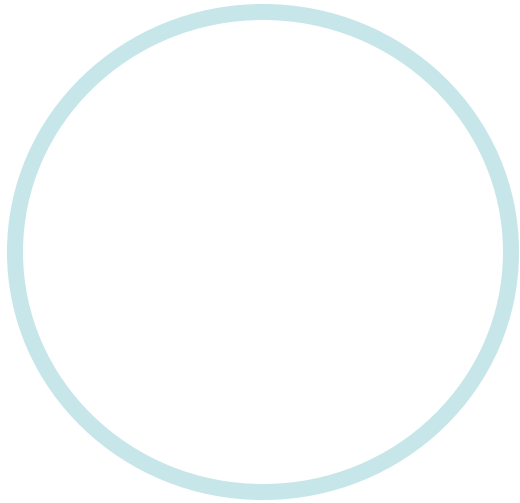
(*lat.* light box)

- **Full angular acceptance**
- **Perfect optical coupling to thick layers of water or scintillator**
- **High ambient pressure**
- **Extreme robustness**

→ SPHERICAL CONFIGURATION

- **Immune to accidental exposure to high light intensities**

→ LIGHT AMPLIFIER (G-APDS)



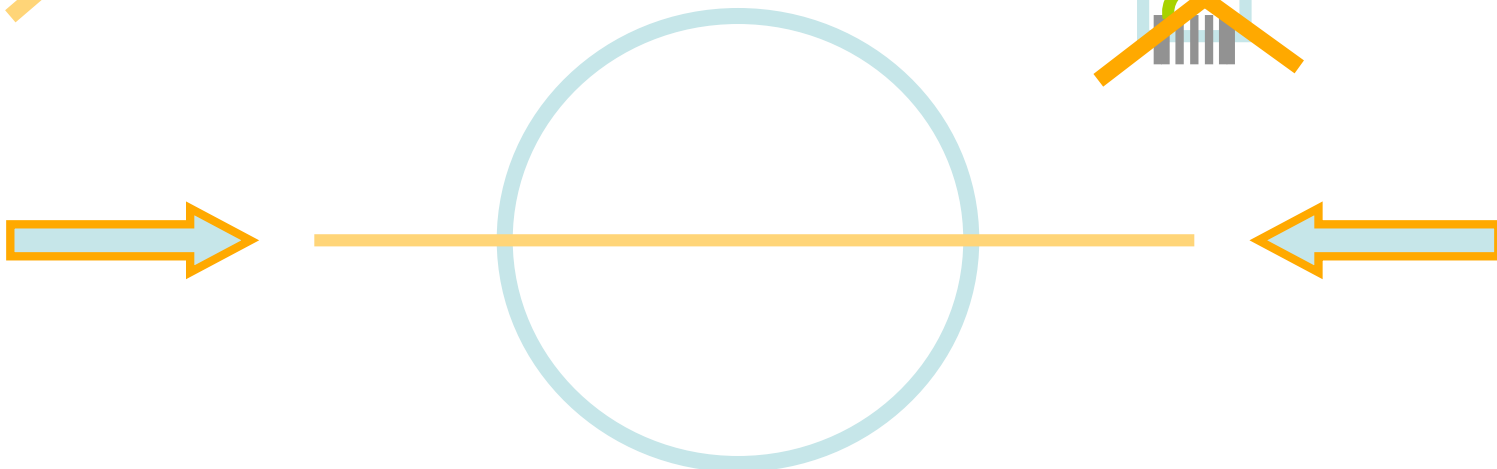
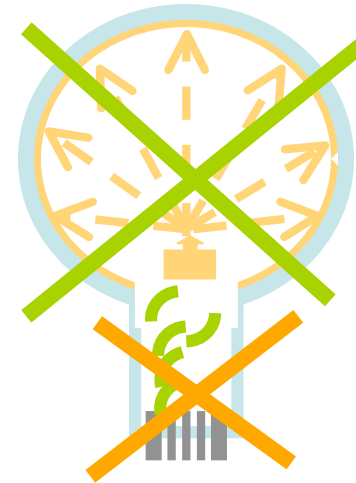
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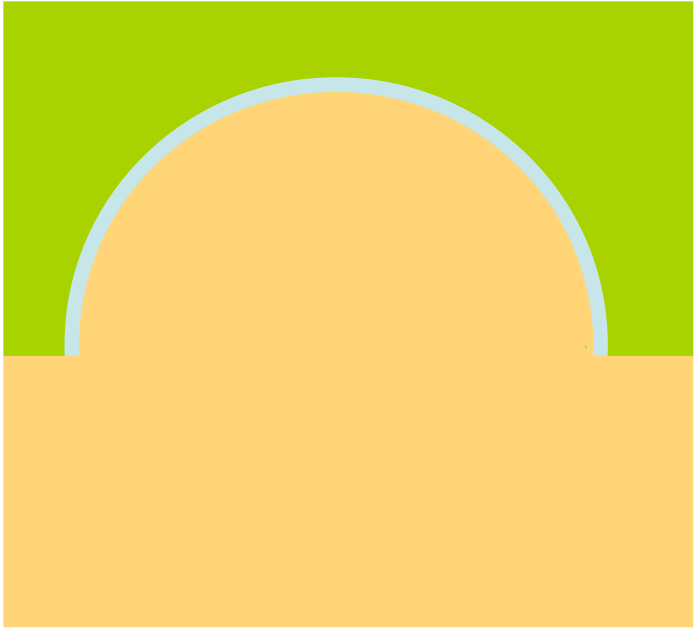
Mass production
High performance

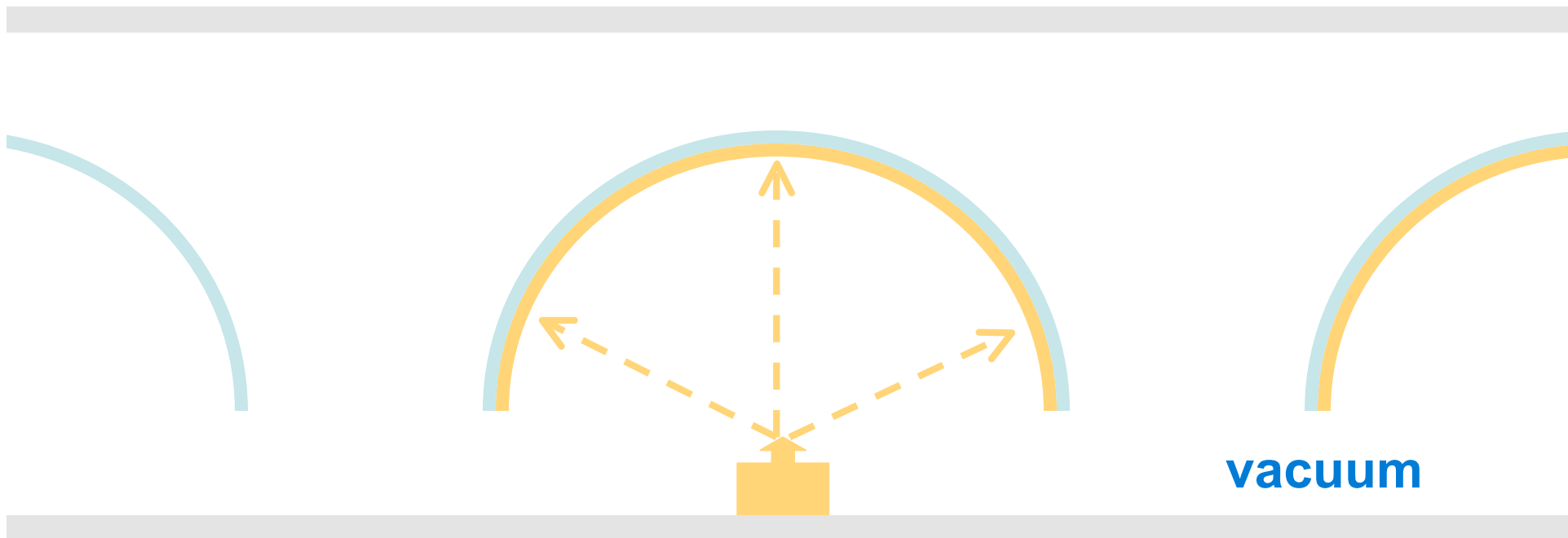
COMPONENTS:
**Industrially
mass-produced**

ASSEMBLY:
Production-line











?



Special marriage:

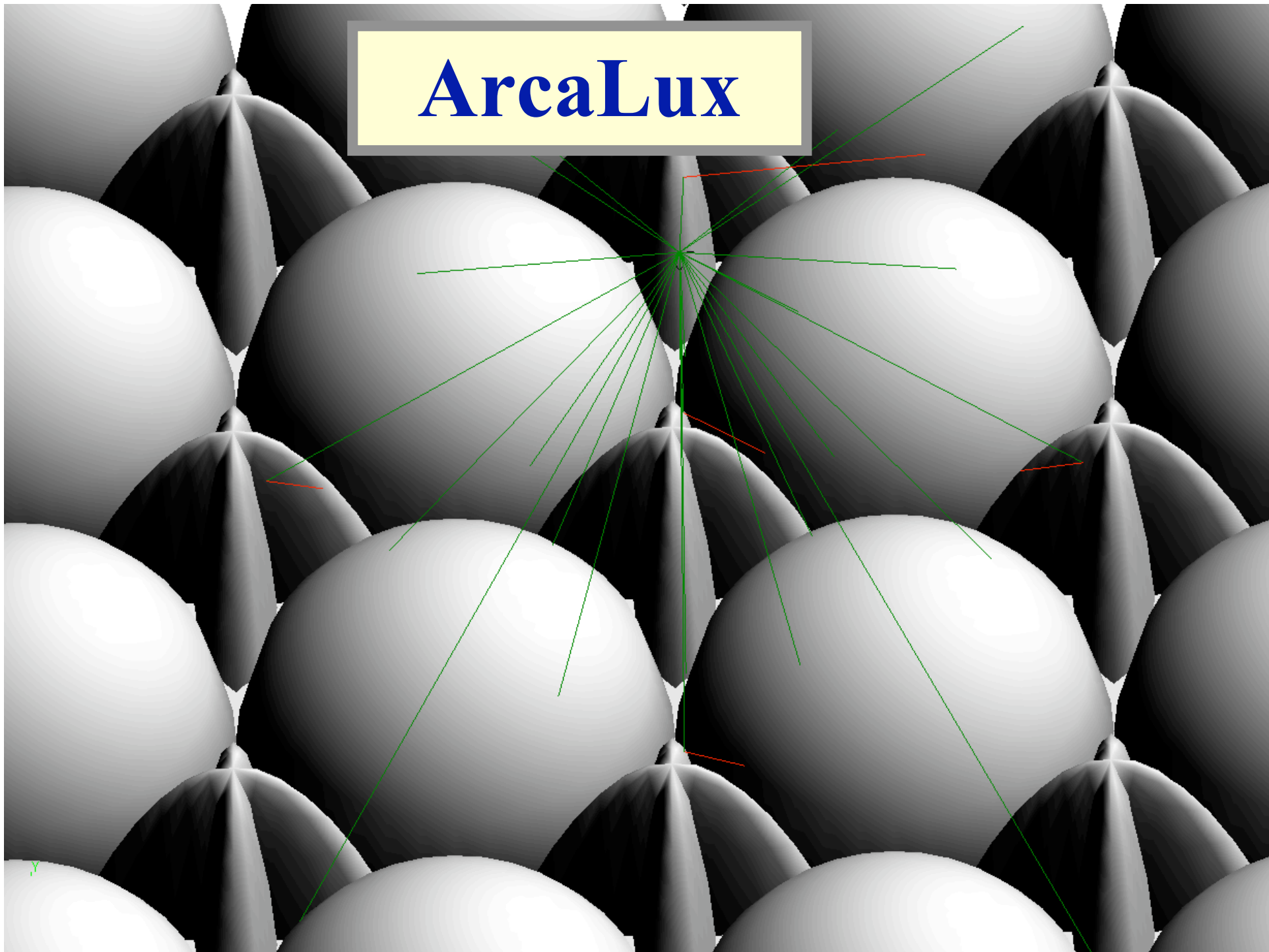
~ 0% dead area

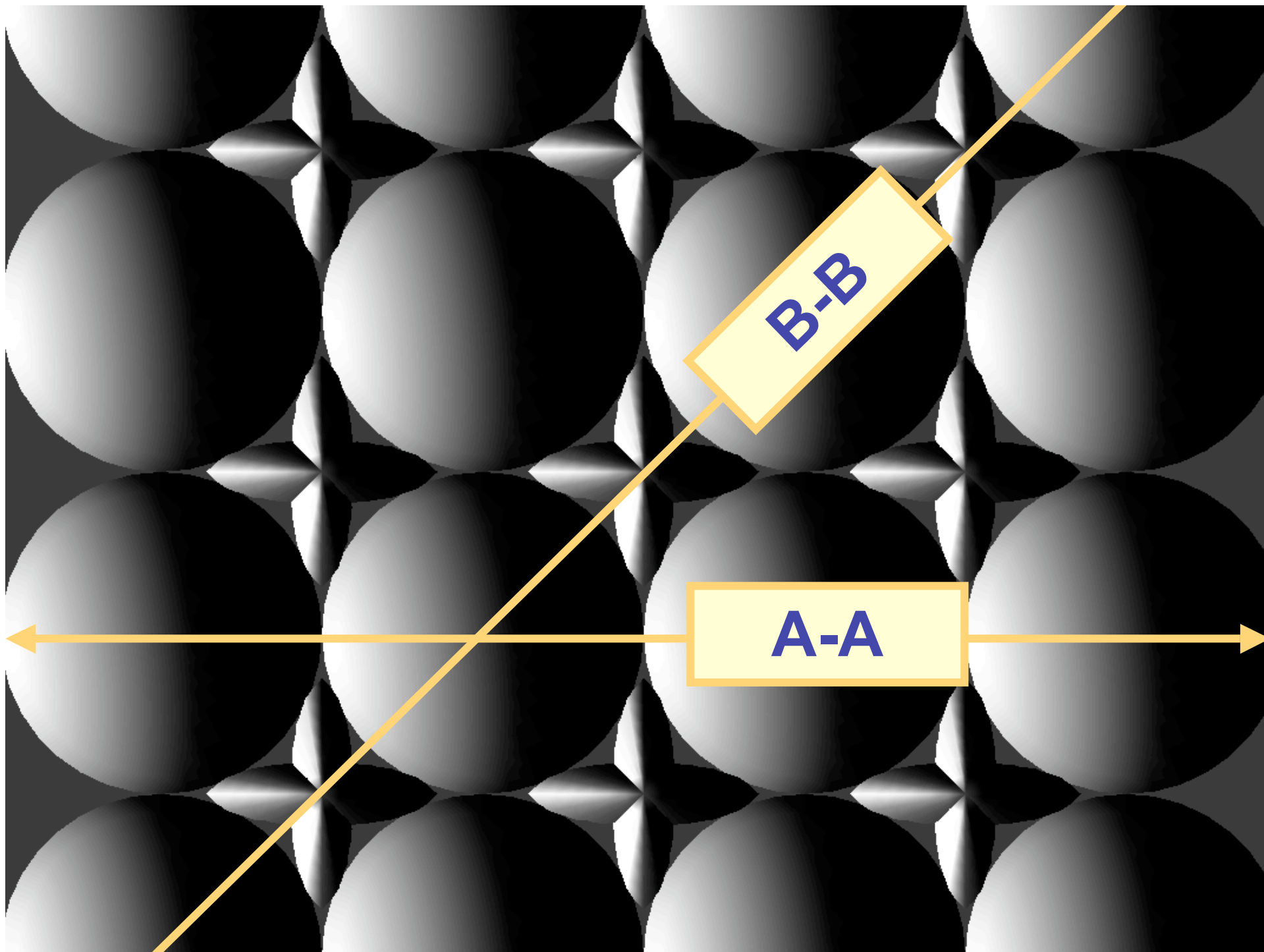
Long-lasting – the internal pollution - internally absorbed

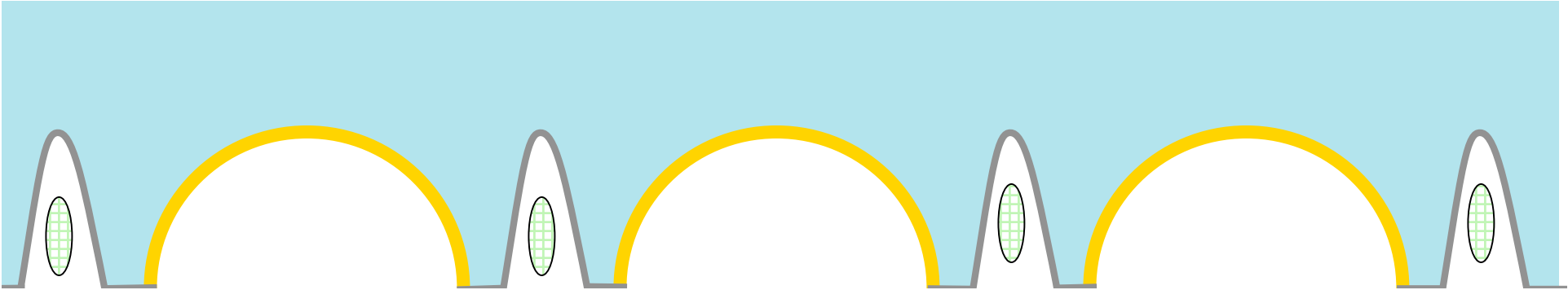
Highly resistant to pressure from outside

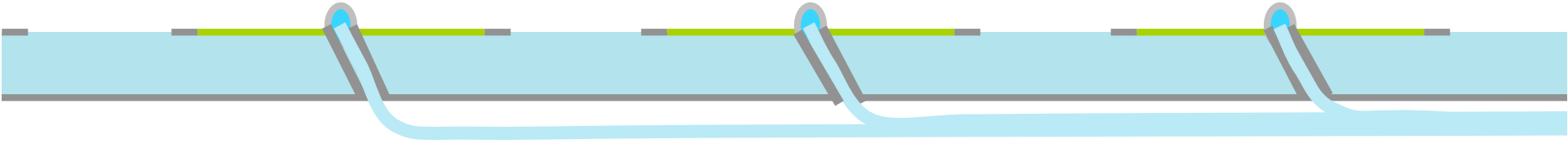
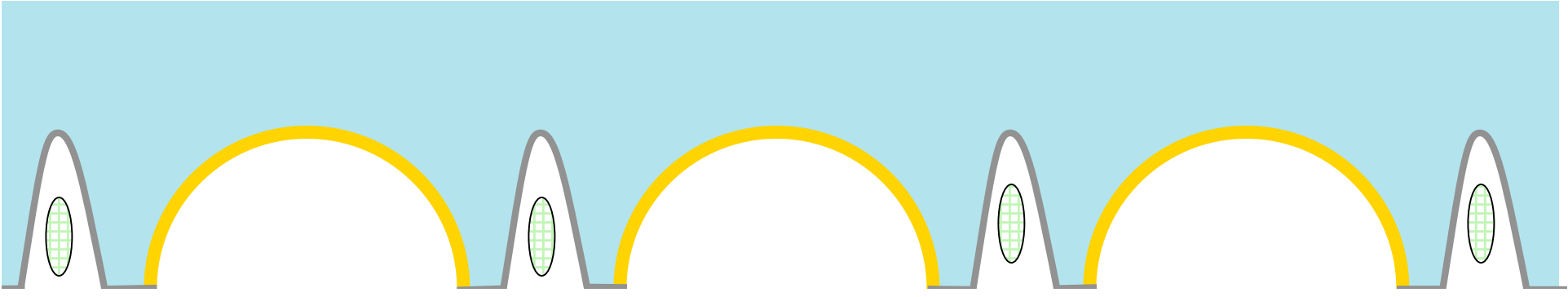
Ready for mass-production

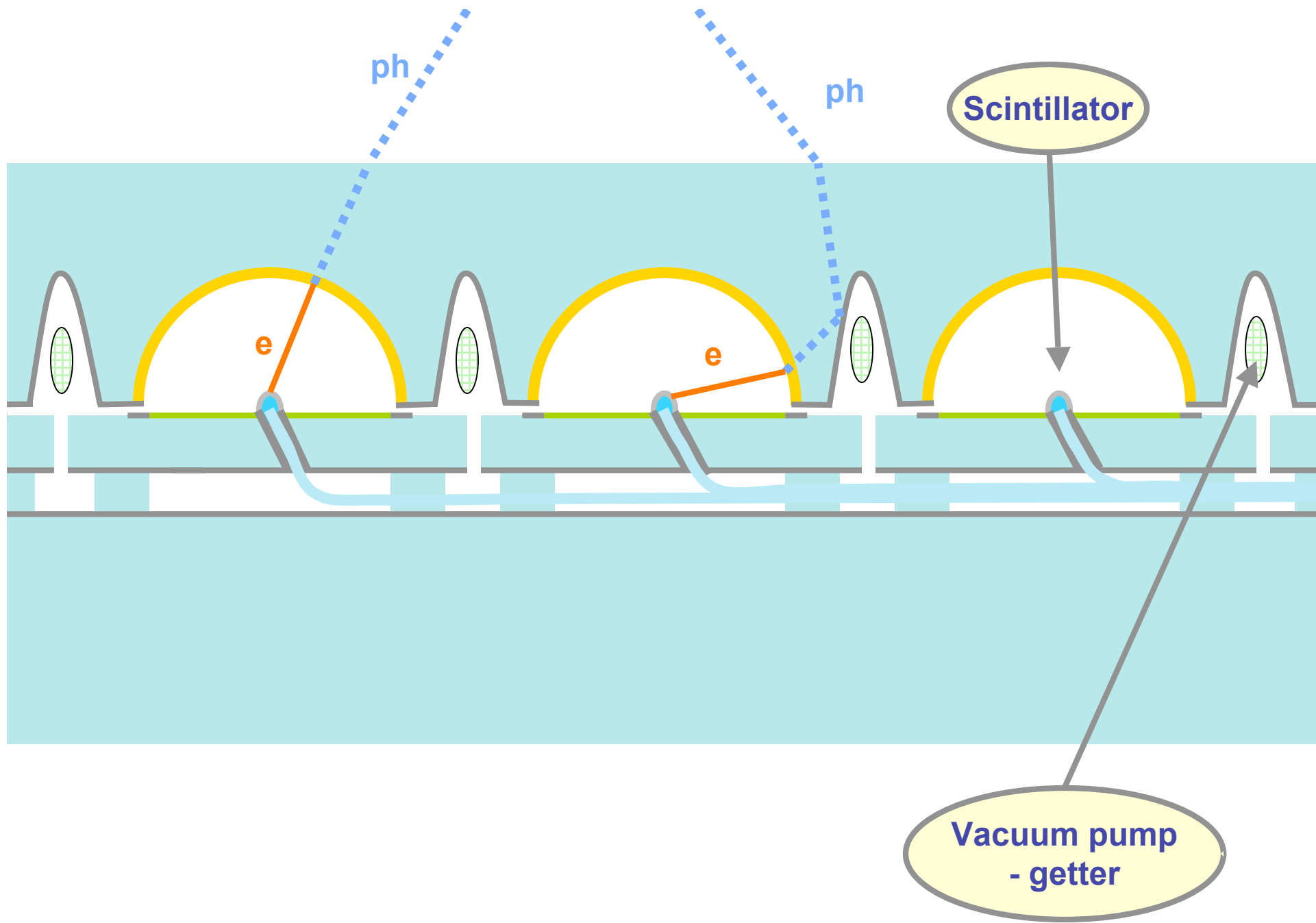
ArcaLux

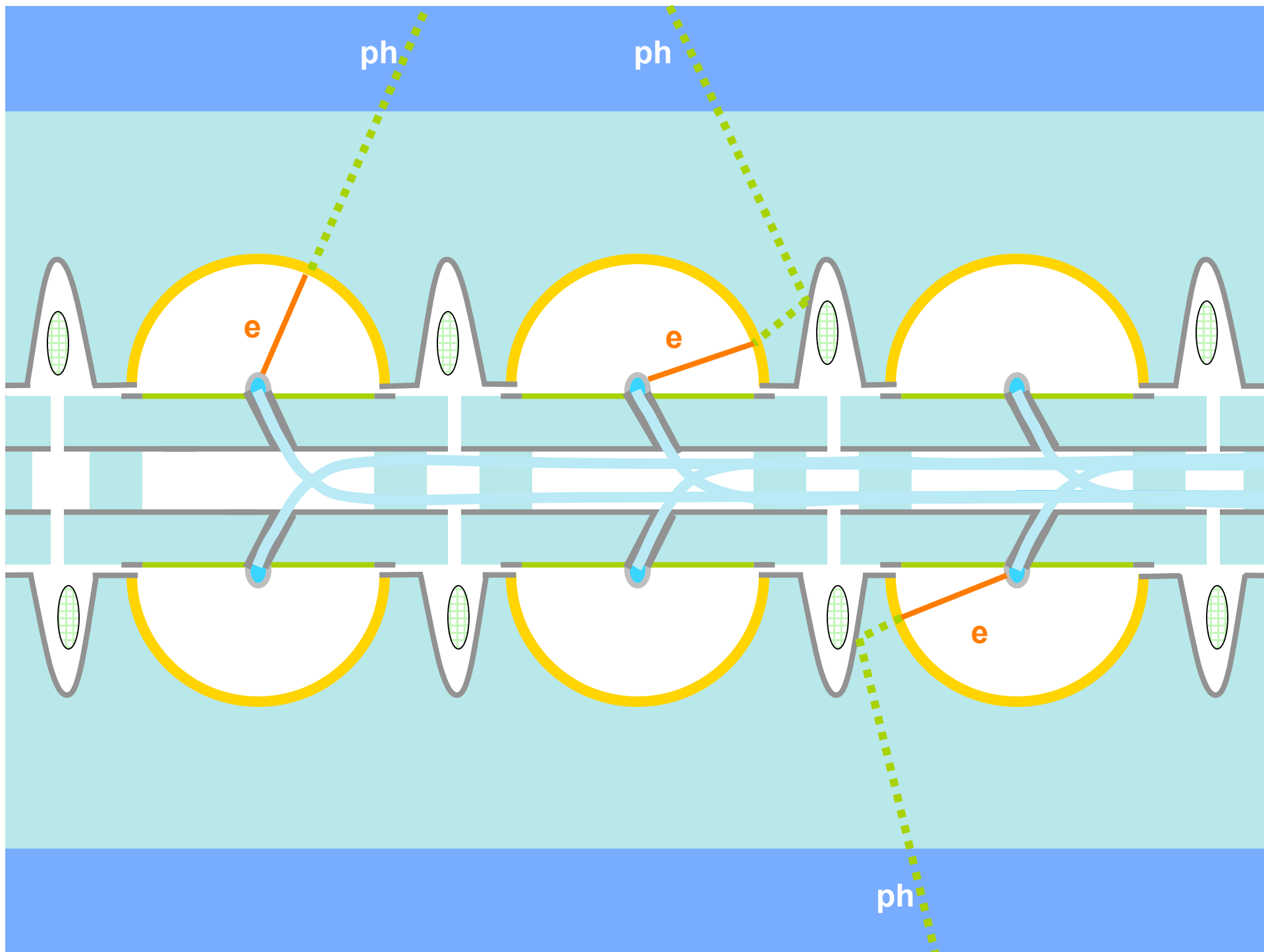






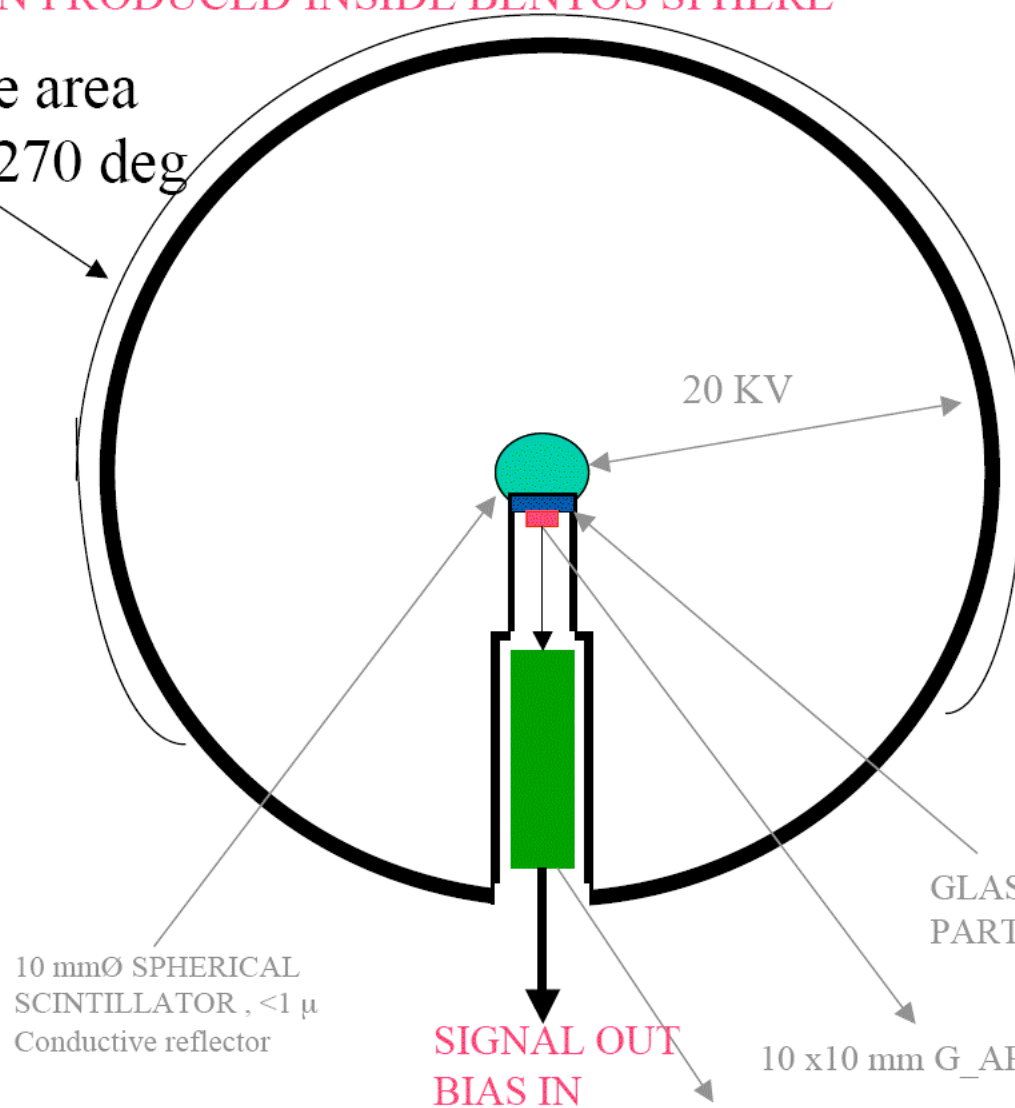






A SPHERICAL SOLUTION WITH SPHERICAL SCINTILLATOR, SIMPLE PRODUCTION
 5 STERAD, MINIMAL TIME JITTER, ELECTRONICS CAN BE LOCATED IN STEM
 MAY BE EVEN PRODUCED INSIDE BENTOS SPHERE

Cathode area
 covers 270 deg



POSSIBLE NEW SCINTILLATORS
 FOR HIGHER LIGHT YIELD,
 FASTER OPERATION

a) BrillLanCe from Saint-Gobain

- High light yield > 60 photos/KeV
- Fast τ : 16 nsec
- Caveat: extremely hygroscopic

b) LSO,LYSO

- High light yield. 25-30 photos/KeV
- Fast 35-40 nsec
- Easy to handle

c) ZnO

- Medium light yield, 10 photos/keV
- Ultrafast \approx 1 nsec
- Exotic material
- No commercial production
- Small xtals

GLASS LIGHT GUIDE
 PART OF VACUUM SEAL

10 x 10 mm G_APD

HT. ELECTRONICS

E. Lorenz, D. Ferenc, Elba 2006, NIMA

THE QUASAR

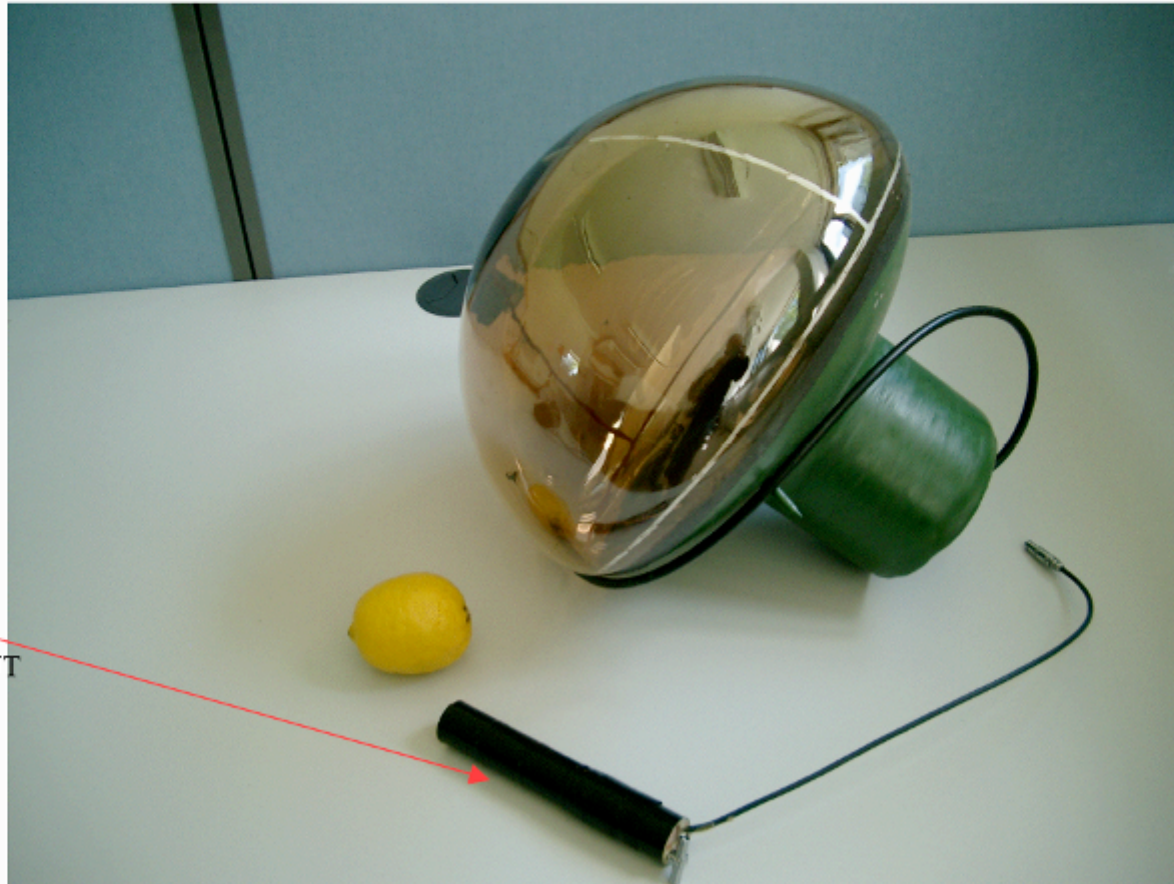
IMPROVED VERSION OF THE SMART PMT

- LARGE ACTIVE AREA/TOTAL VOLUME
- SYMMETRIC PHOTOELECTRON COLLECTION
- PRACTICALLY 100%PHOTOELECTRON COLLEFFICIENCY
- NO NEED FOR BLEEDER CURRENT -> VERY LOW HT POWER
- ALREADY IN LONGTERM USE IN LAKE BAIKAL
- RELATIVELY CHEAP
- CAN DETECT SINGLE PHOTOELECTRONS,
- F-FACTOR ≈ 1.3

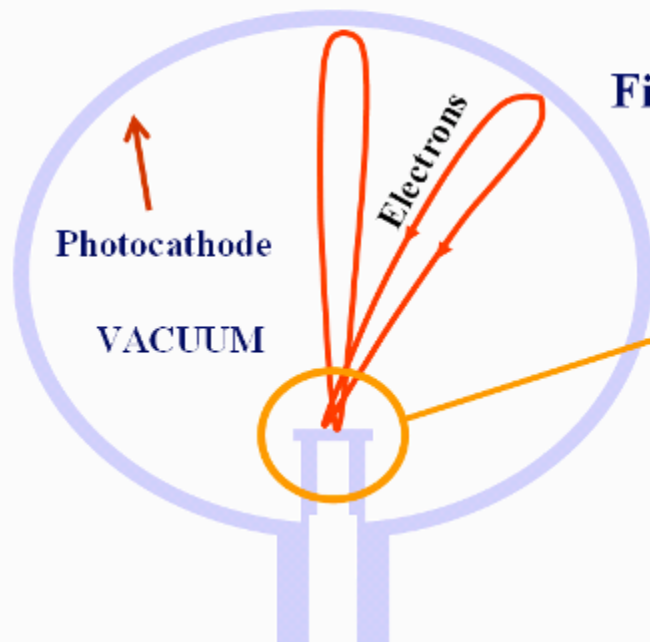
- CRYSTAL WITH LONG DECAY TIME
- RELATIVELY LOW LIGHT YEALD
- PRODUCTION STOPPED

THE FOLLOWING TESTS HAVE BEEN
CARRIED OUT WITH A QUASAR

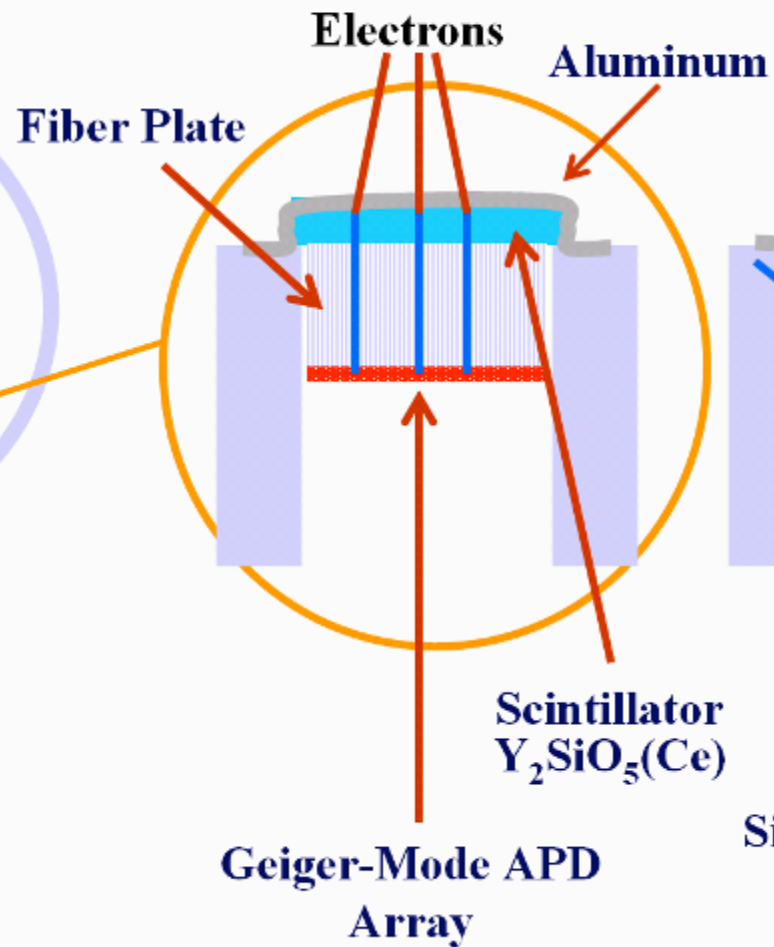
SECONDARY
PMT TO READ OUT
CRYSTAL



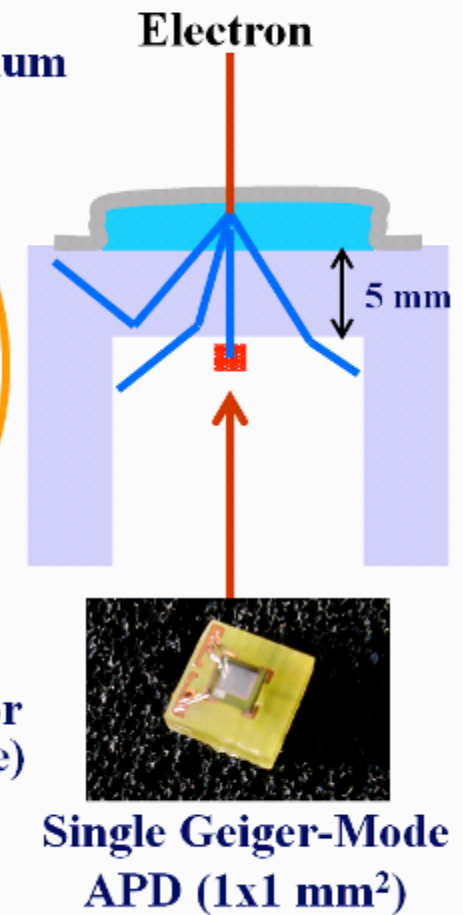
HEMISPHERICAL LIGHT AMPLIFIER



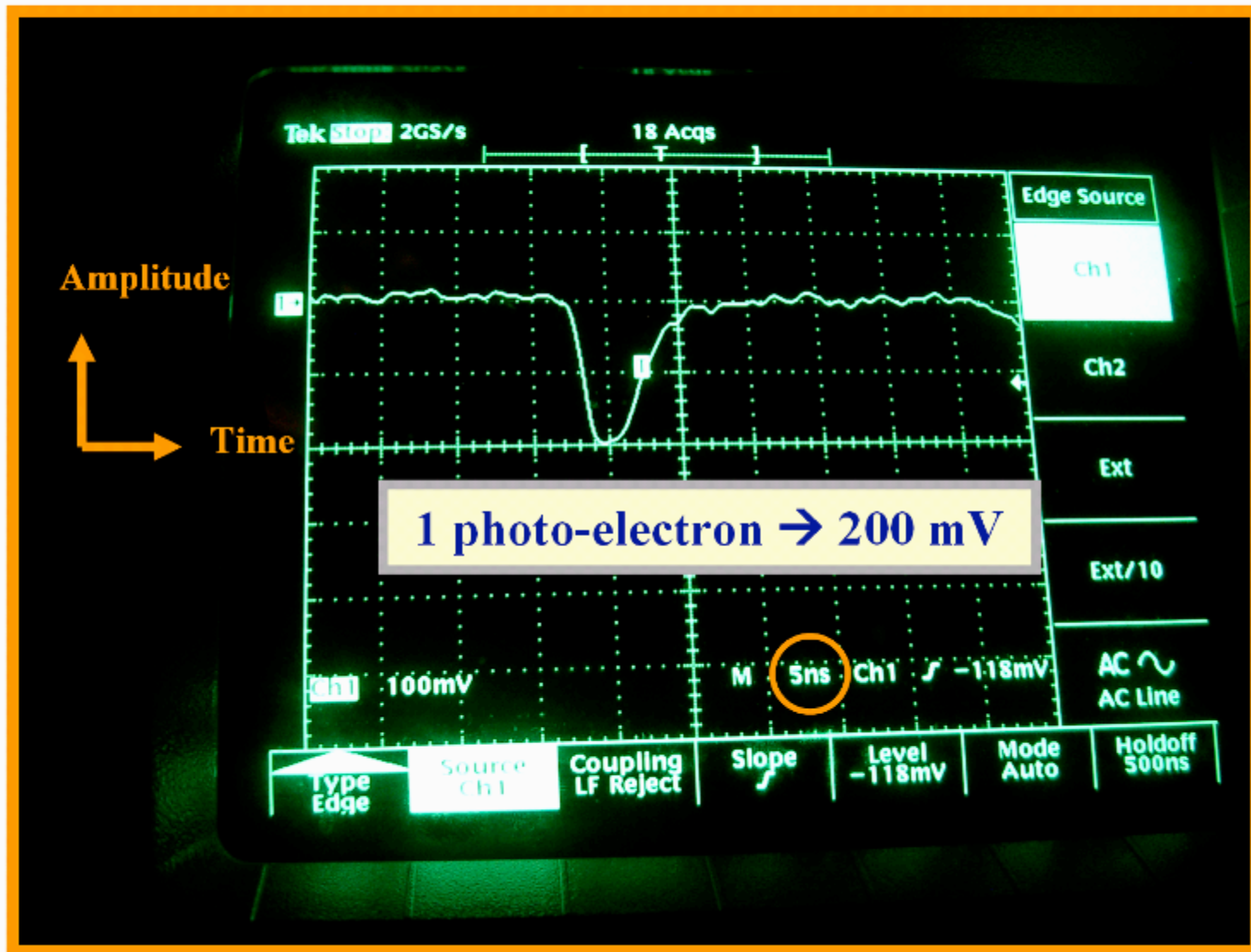
THE ULTIMATE DESIGN



CURRENT PROTOTYPE SETUP



A Typical Single-Photon Signal in the Geiger-mode APD



Conclusion

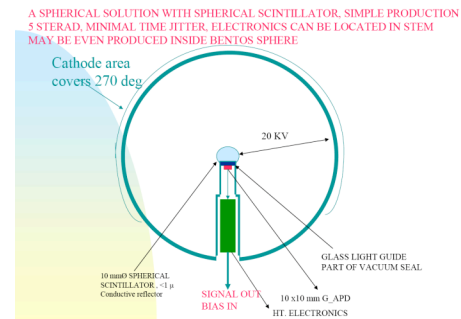
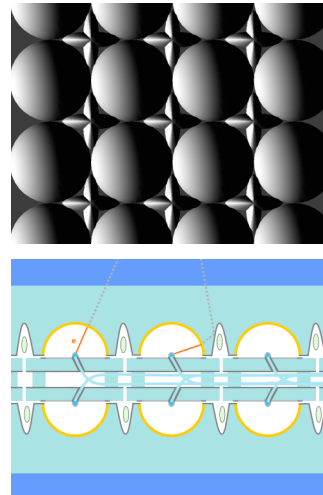
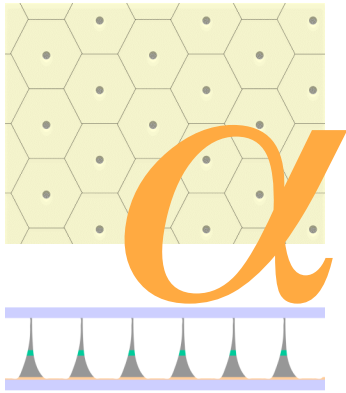
**ULTIMATE:
FLAT-PANEL**

**INTERMEDIATE:
HEMISPHERICAL
Light Amplifier**

α

ReFereNce

ArcaLux



For Dense Media (water, scintillator)

ArcaLux

